

Climate Extremes and Rossby Waves

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¹NASA/GMAO; ²SSAI

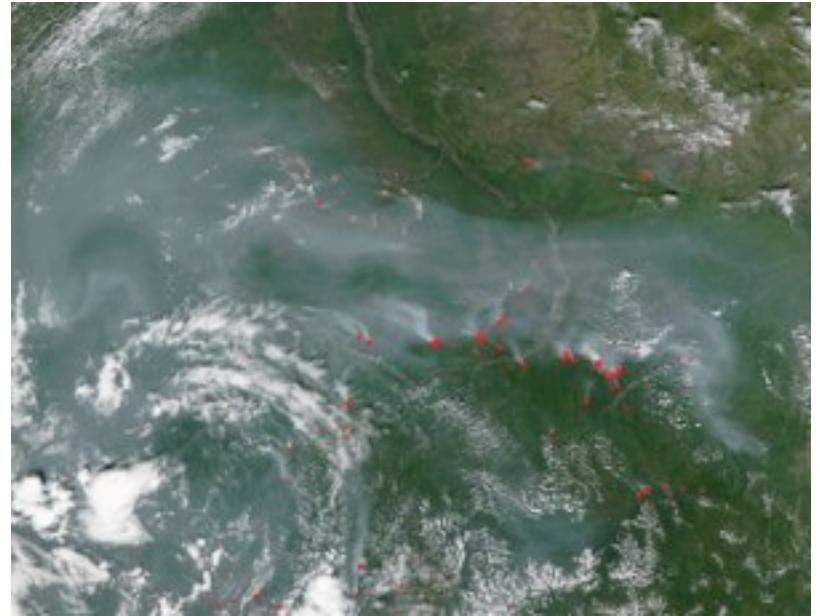
NASA/GSFC, Bldg. 33, Rm. H114, 10:00am

13 September 2011

Introduction

July: Russian Heat Wave and Fires

- Central Russia with [temperatures above 30°C](#) for an entire month.
- “The central city of Volgograd was Russia’s hottest city with [temperatures hovering above 40° Celsius](#) (104 F) for the past few days, hotter than Cairo, Tashkent, Tehran and New Delhi.” The extreme heat is causing the former permafrost tundra to smolder and burn.
- Across Russia, “the emergencies ministry used 18 planes and 38 helicopters in an effort to douse a total of [220 wildfires](#), including 28 major blazes covering nearly 12,000 hectares,” a Moscow-based spokeswoman told AFP. “A major fire started in the southern Rostov region on Tuesday causing two days of explosions of World War II-era shells embedded in a local forest.”



2010 Russian Heat Wave



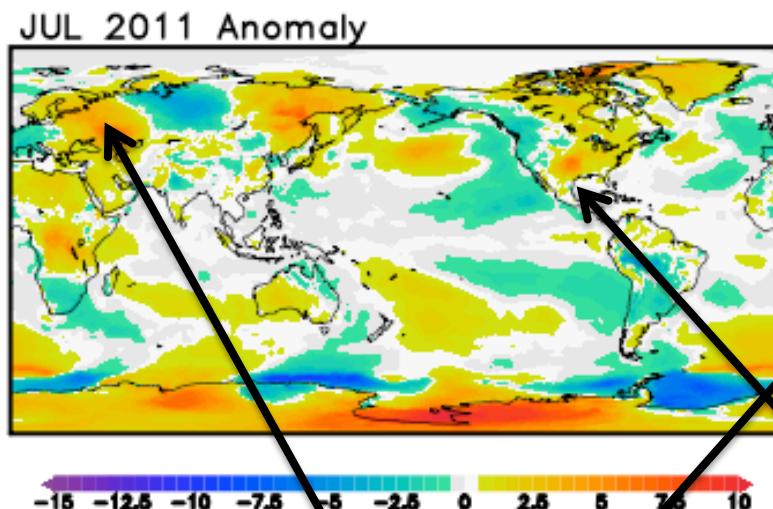
In this July 28, 2010 satellite image released by NASA, smoke from fires near Moscow is visible over central Russia. The small red boxes indicate fires, the image covers 900 km (560 mi) from side to side. The city of Moscow is located near the left edge, in the lower third. (AP Photo/NASA) #

The summer of 2010 brought intensely [hot weather](#) to large portions of the northeastern U.S., central Europe, and Russia. [Russia](#) was especially hard hit as a heat wave — with daily high temperatures hitting 100°F — contributing to the deaths of as many as [15,000 people in Moscow](#) while wildfires tore across more than 2,900 square miles in the central and western part of the country. Drought accompanied the record high temperatures decimating [more than a quarter of Russia's grain harvest](#). Economists estimated the grain losses cost the Russian economy upwards of \$15 billion dollars.

<http://www.climatecentral.org/blogs/historical-perspective-on-the-russian-heat-wave-of-2010>

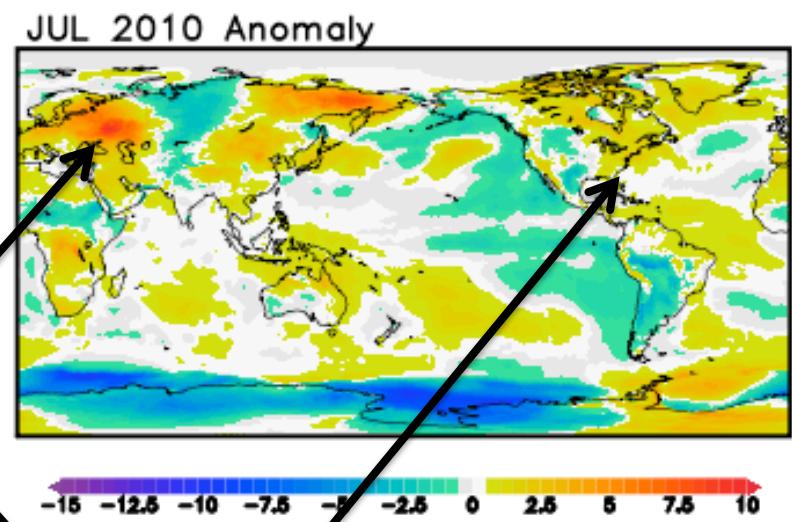
Temperature at 2 meters

July 2011



Russian Heat Waves

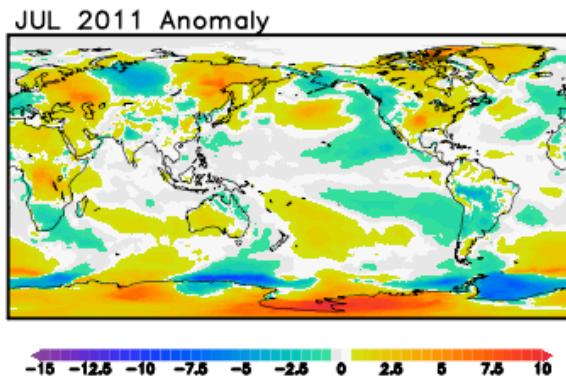
July 2010



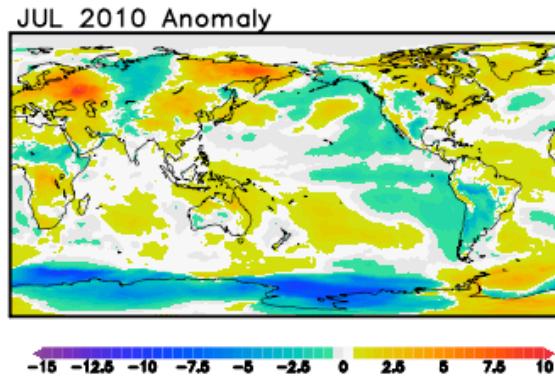
US Heat Waves

Temperature at 2 meters

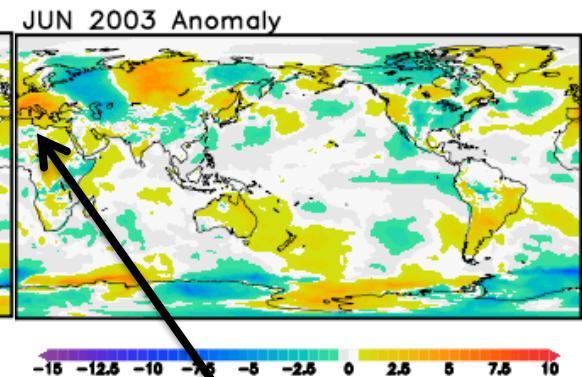
July 2011



July 2010



June 2003



°C

European Heat Wave

Recent Work on the 2010 Russian Heat Wave

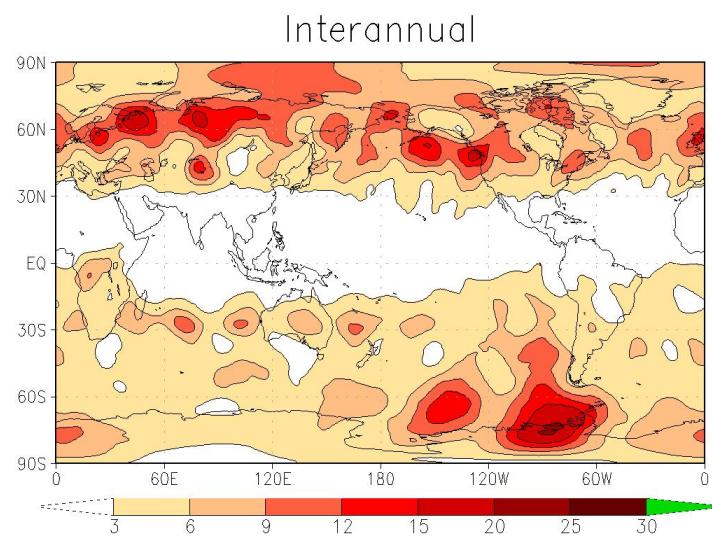
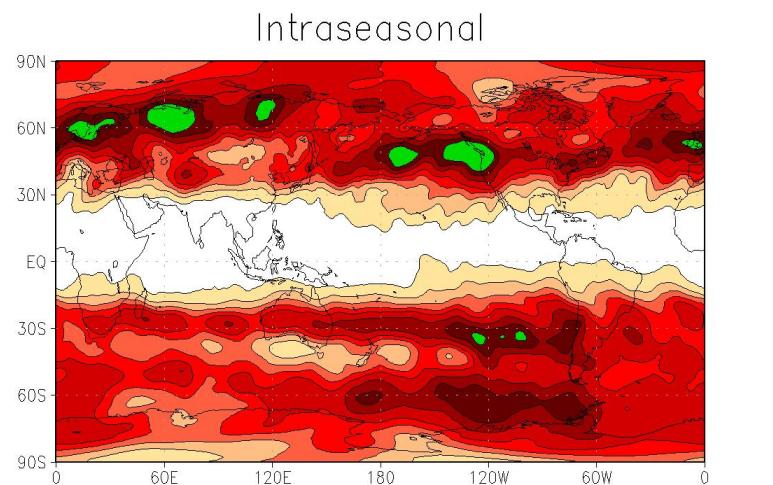
- *The 2010 Pakistan Flood and Russian Heat Wave: Teleconnection of Hydrometeorologic Extremes, Lau and Kim, 2011, J. Hydrometeorology*
- *Was there a basis for anticipating the 2010 Russian heat wave? Dole et al., 2011, GRL*
- *Warm Season Subseasonal Variability and Climate Extremes in the Northern Hemisphere: The Role of Stationary Rossby Waves, Schubert, S., H. Wang, and M. Suarez, 2011, J. Climate.*

Outline

- Structure of Large Scale Summer Variability
 - Links to surface meteorology and extremes
- Physical Mechanisms of Rossby Waves
 - Role of jets and nature of atmospheric forcing
- Role of SSTs and Land Surface
 - The 2010 Russian heat wave
 - The 2011 US heat wave

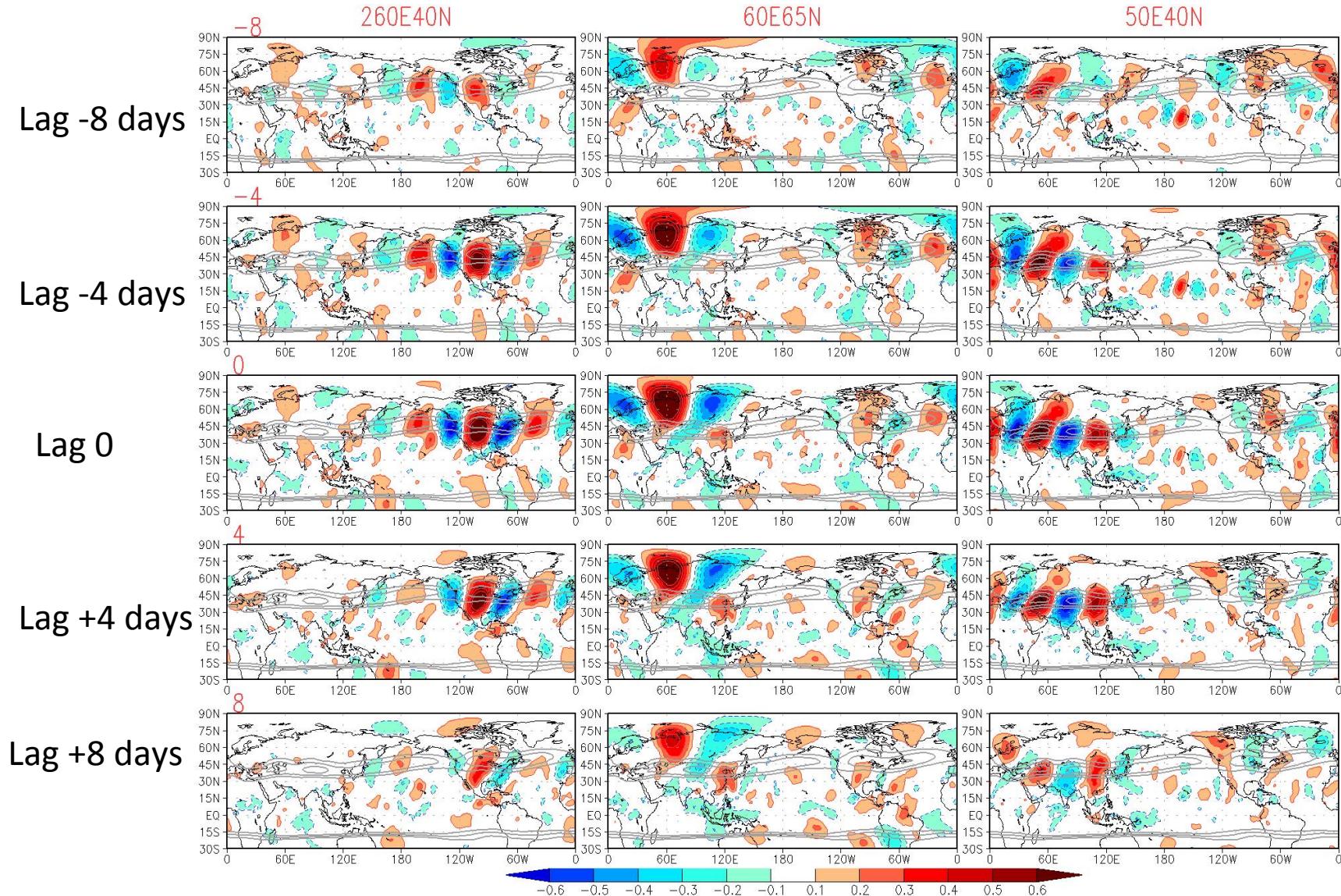
Variance of V250mb (JJA 1979-2008)

(30-90 day filter)

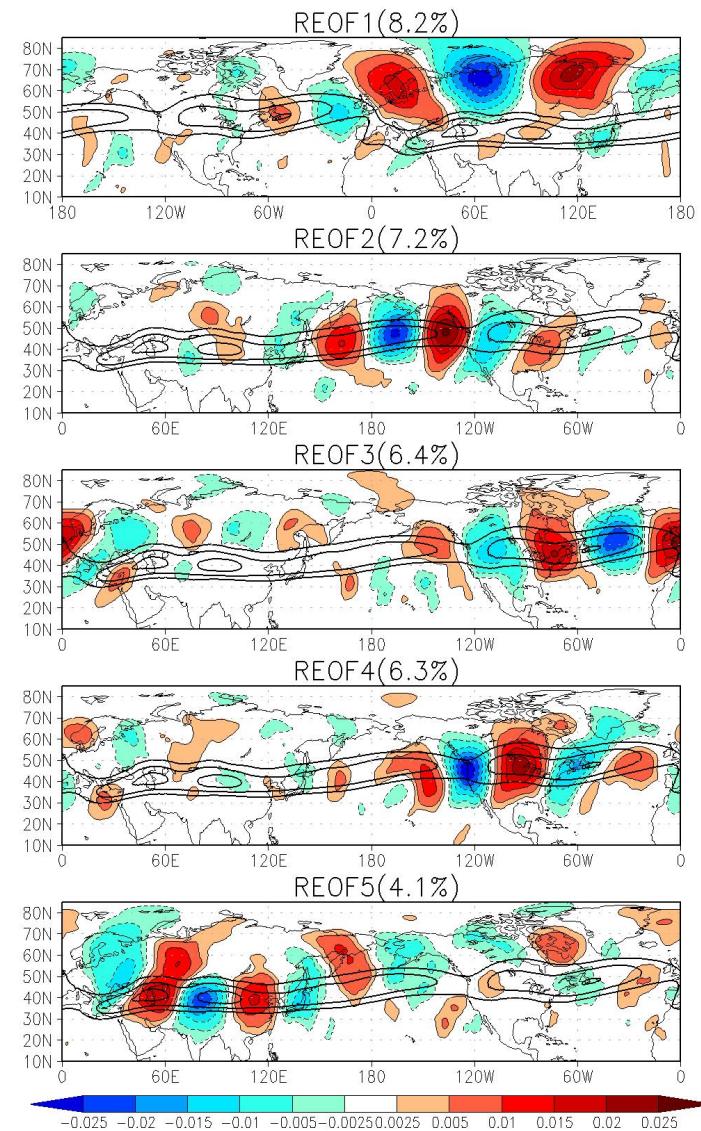


$(\text{m/s})^2$

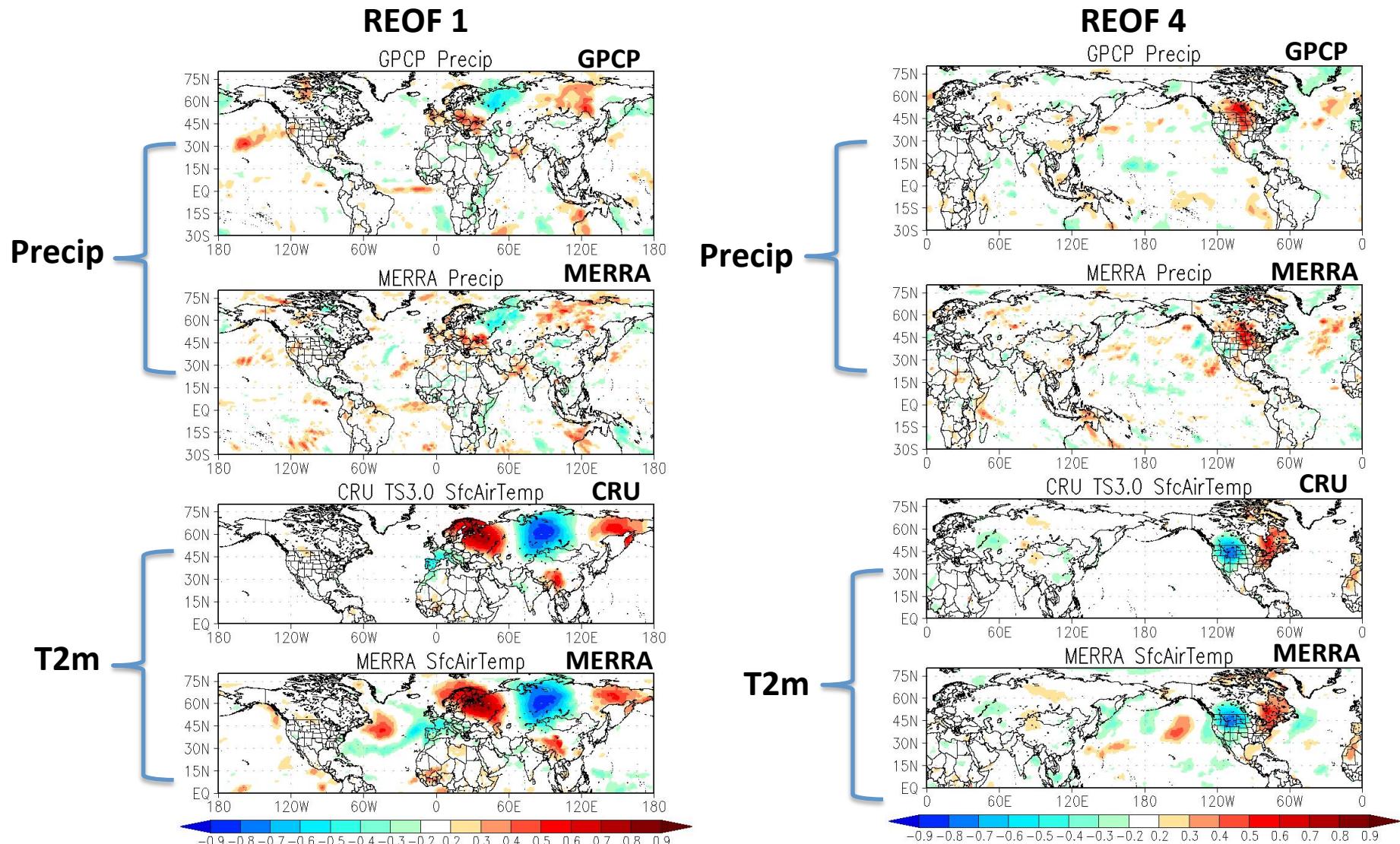
Lead/Lag Correlation of V-250mb at Different Locations with V250mb Everywhere (JJA 1979-2008, 30-90 day filter)



Leading Rotated EOFs of Intraseasonal (Monthly JJA) V250mb

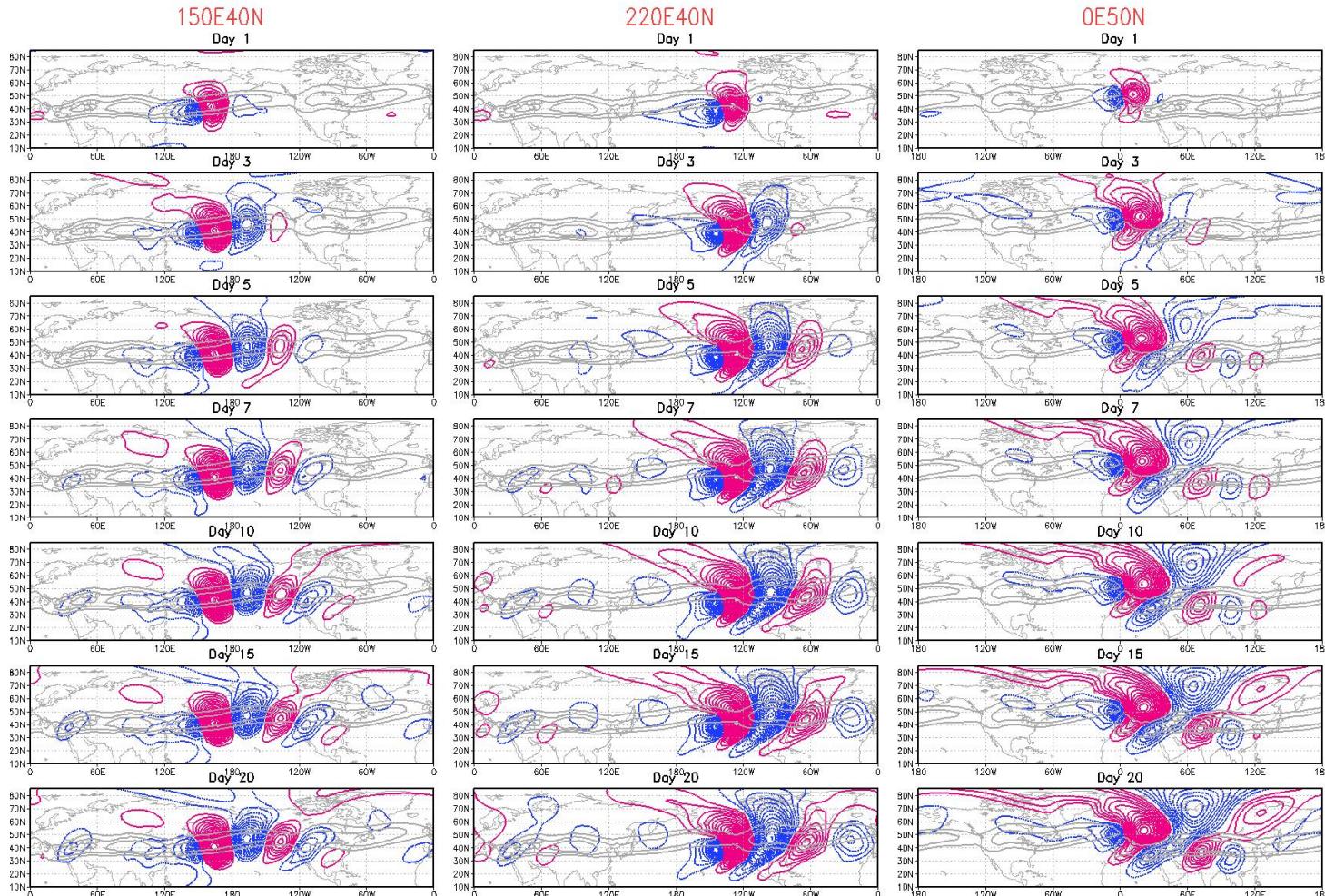


Correlations Between Leading v250mb REOFs and Precipitation and T2m



Stationary Wave Model (SWM, Ting and Yu 1998) Results

The time evolution of the response of the eddy v-wind at $\sigma=0.257$ to an idealized vorticity source at:



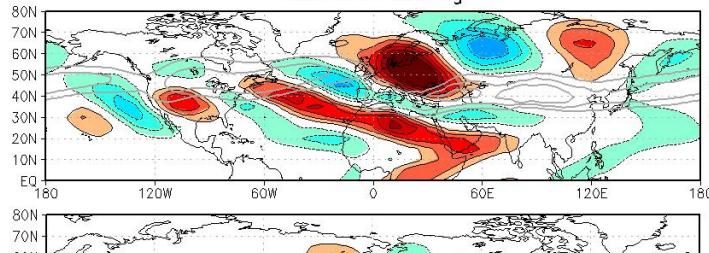
MERRA JJA Base State

Eddy V-wind $\sigma=.257$

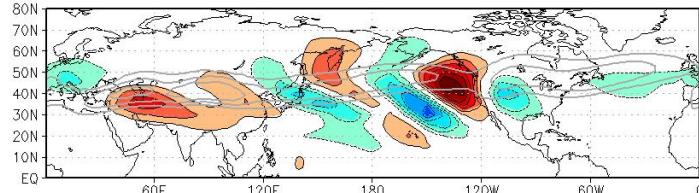
“Optimal” Heat Source Pattern

REOF 1

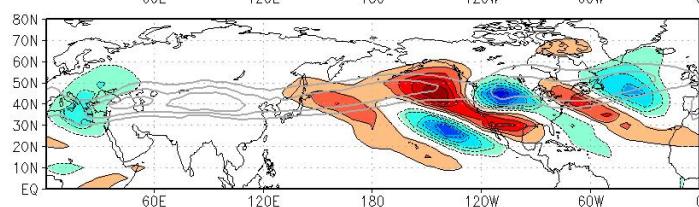
Diabatic Heating



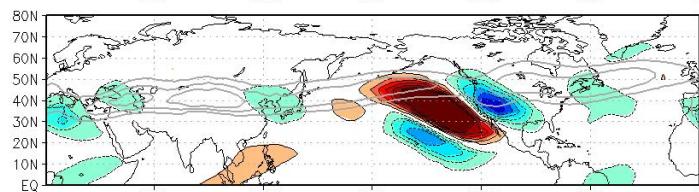
REOF 2



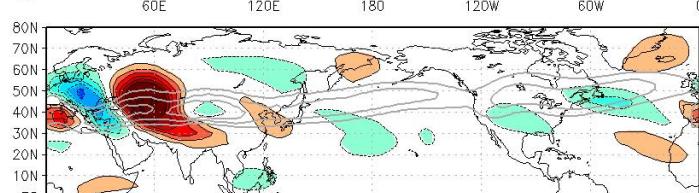
REOF 3



REOF 4

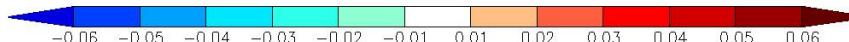
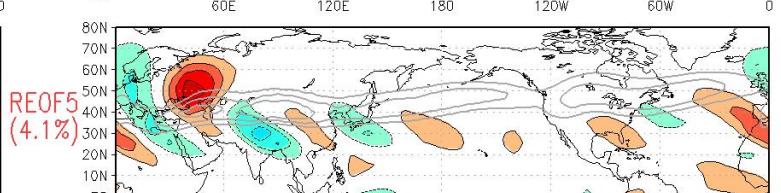
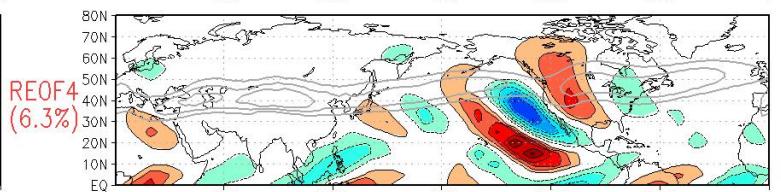
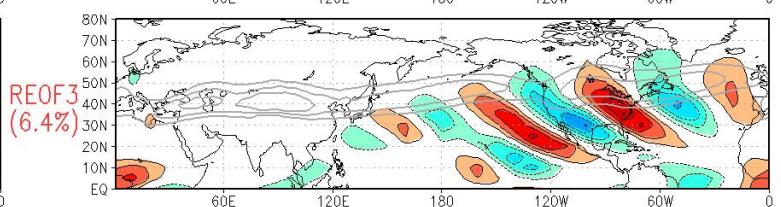
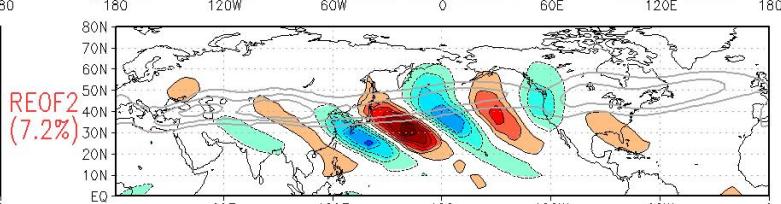
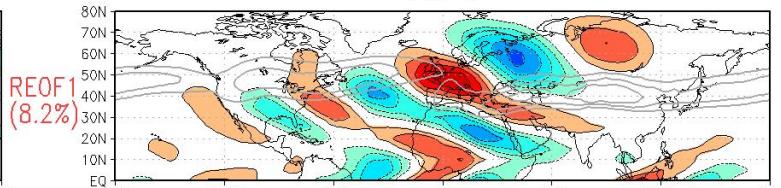


REOF 5

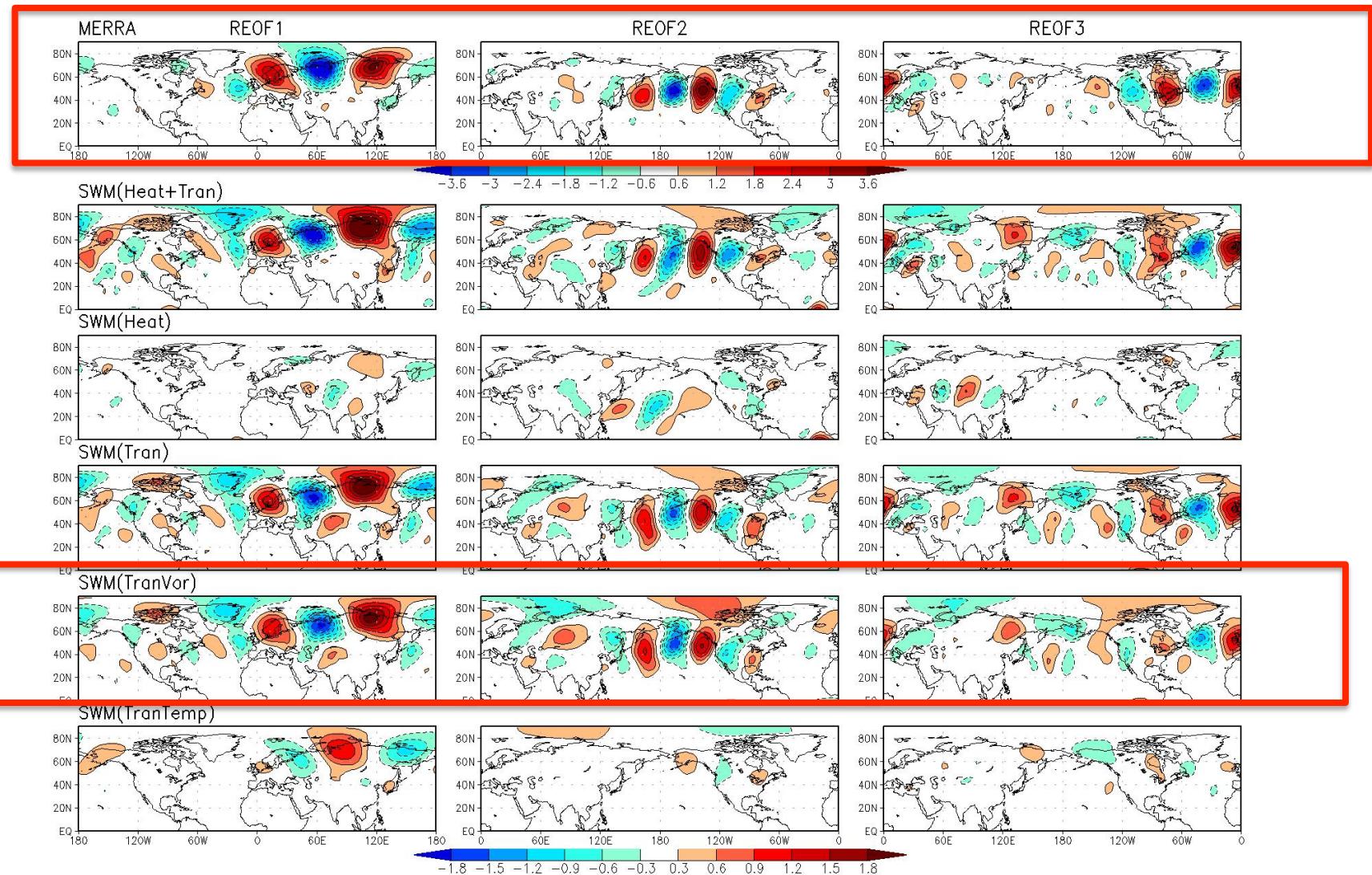


“Optimal” Vorticity Source Pattern

TranVor



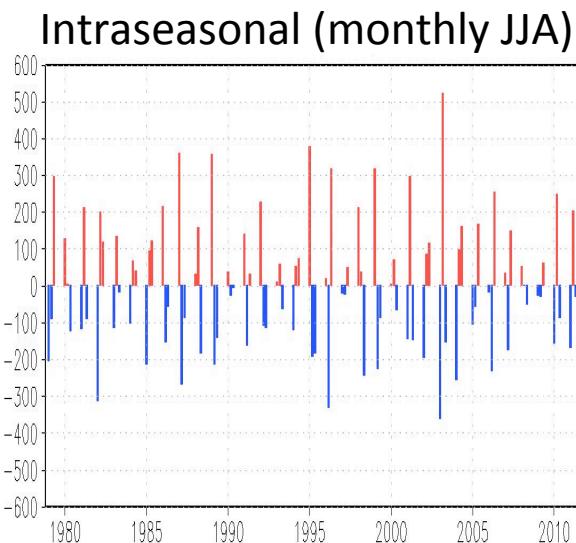
What Forces The REOFs?



Vorticity submonthly transients

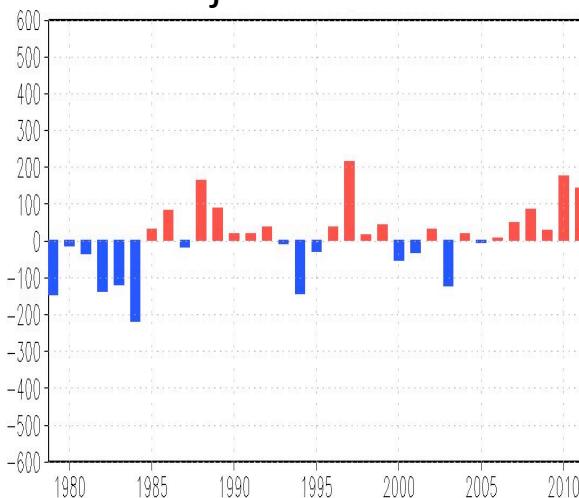
Time Series of v250mb REOF 1 (PC)

2010 July Russian Heat Wave

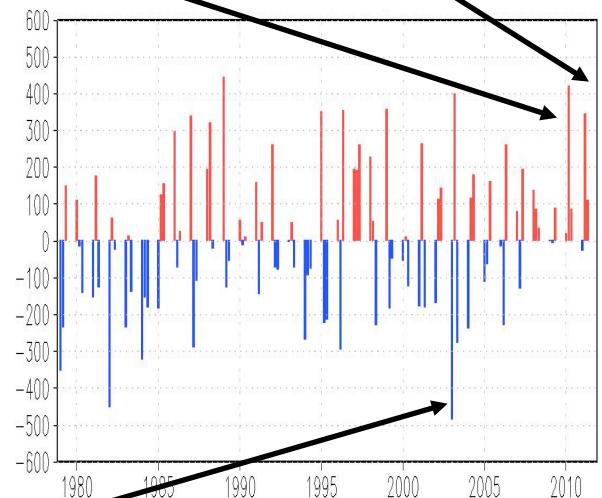


2011 July Russian Heat Wave

Projection on JJA

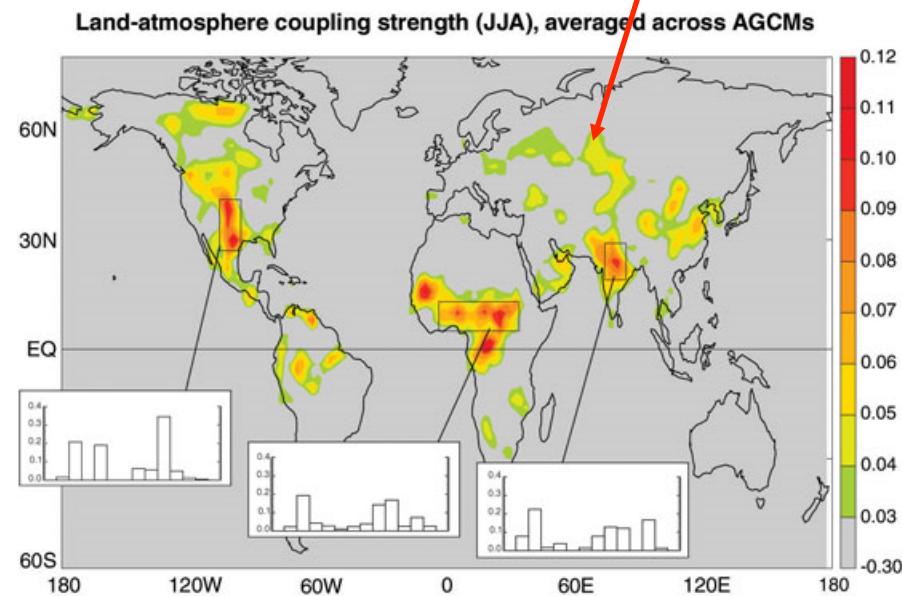


Total



European June 2003 Heat Wave

Indications of land processes over northern Eurasia



Koster et al. 2004

GEOS-5 AGCM Experiments

- Role of SST
- Role of Land
- Focus on:
 - 2010 Russian Heat Wave
 - 2011 US Heat Wave

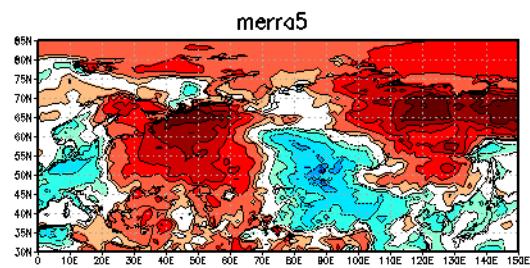
2010 Russian Heat Wave

AGCM experiments (1°) :

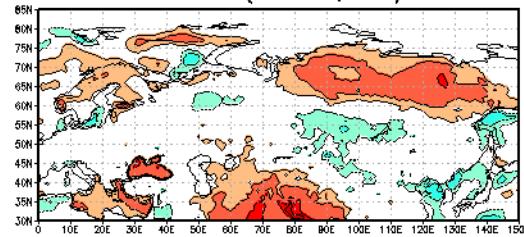
- 1) initialized 1 May, 20 ensemble members, observed SST
 - 2) initialized 1 May, 20 ensemble members, climatological SST
 - 3) initialized 1 January, 40 ensemble members, observed SST
-
- Land and Atmosphere initialized from MERRA
 - Anomalies wrt the mean of 4 ensemble members run for each year 1982-2000

May

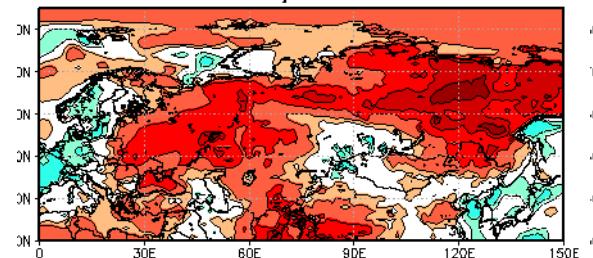
MERRA



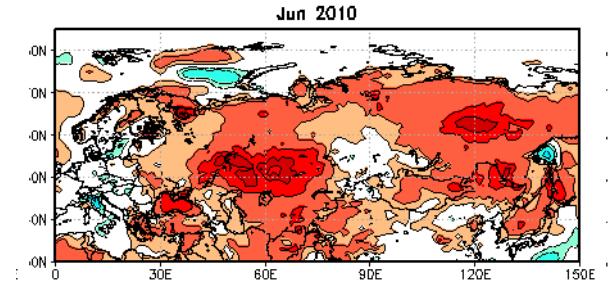
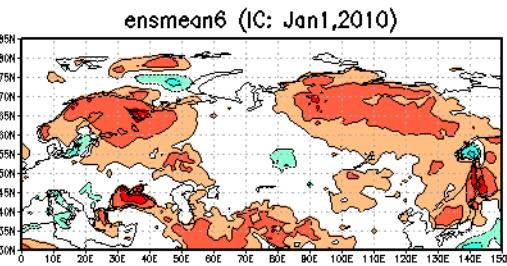
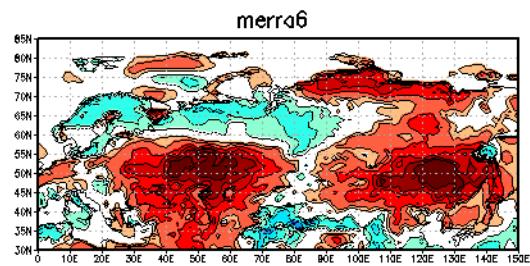
IC (Jan1,2010)
Perturbation runs: 40
ensmean5 (IC: Jan1,2010)



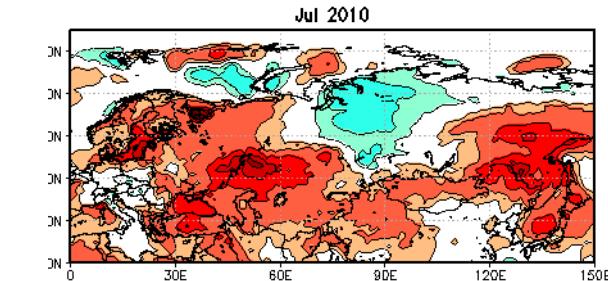
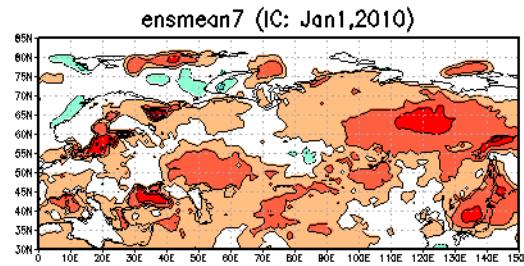
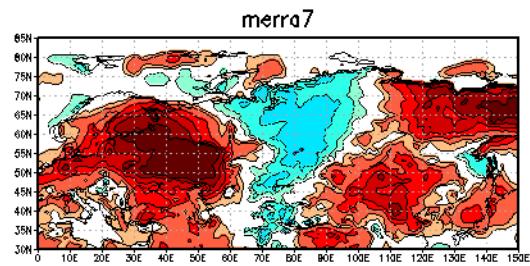
IC (May1,2010)-
Perturbation runs: 20
May 2010



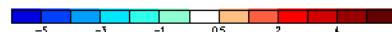
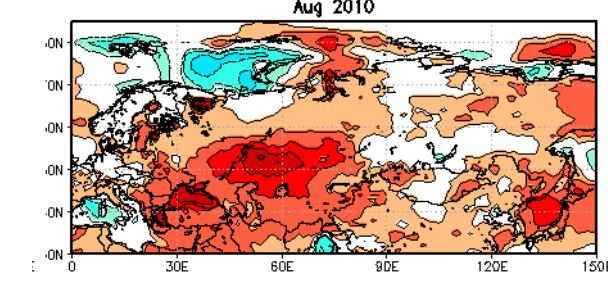
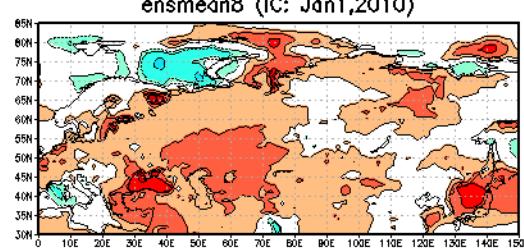
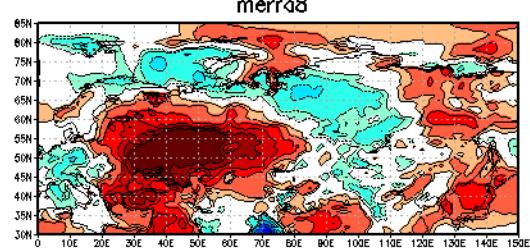
June



July



August



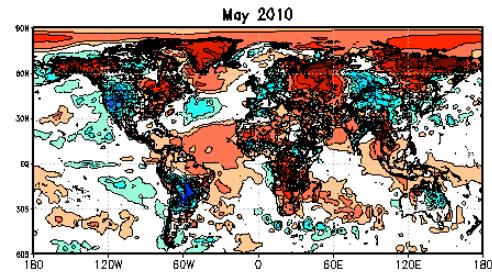
T2m °C

T2m (°C)

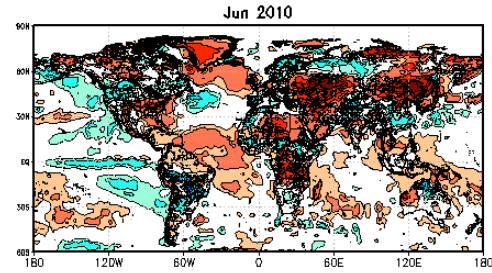
A Developing La Niña

May 2010

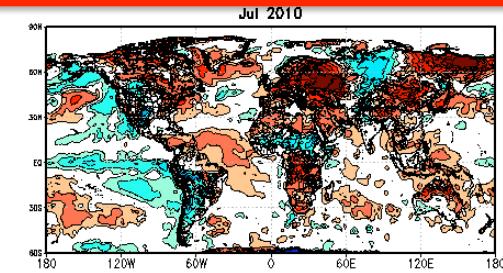
MERRA



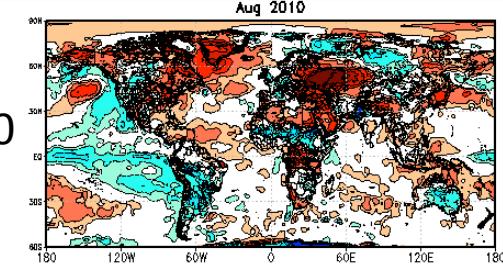
June 2010



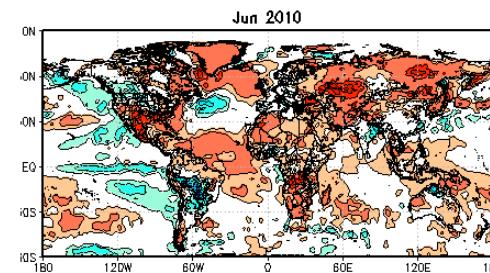
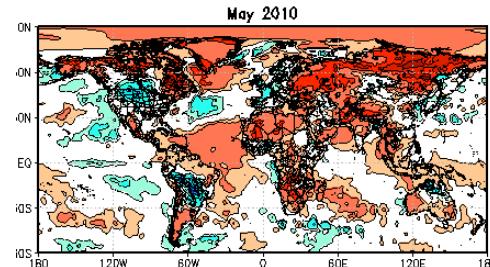
July 2010



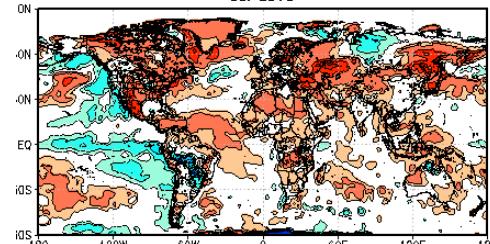
August 2010



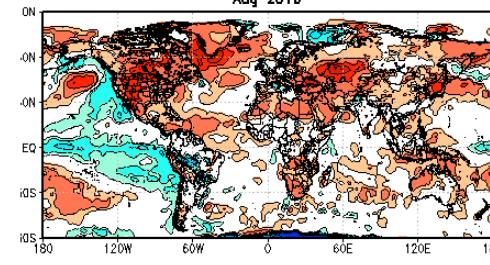
AGCM Obs SST
IC (May 1)



Jul 2010



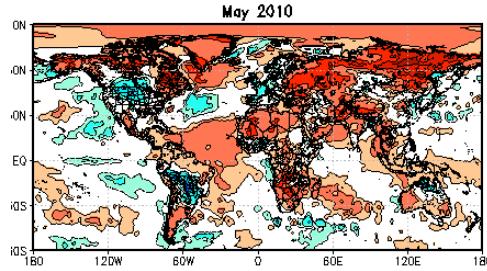
Aug 2010



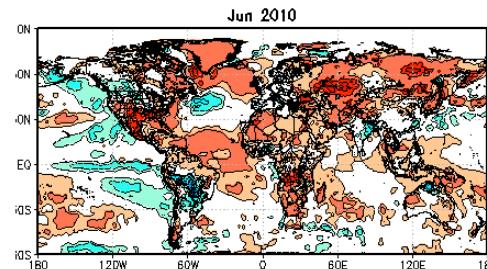
T2m °C

AGCM Observed SST
(IC May 1)

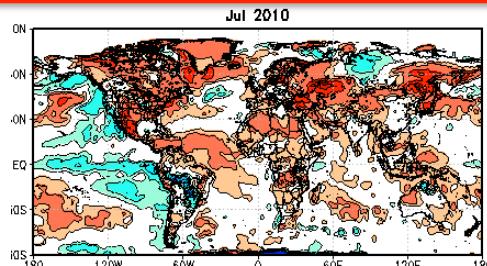
May 2010



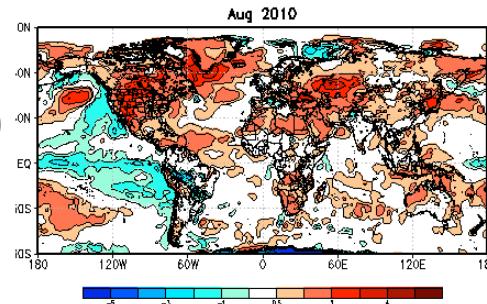
June 2010



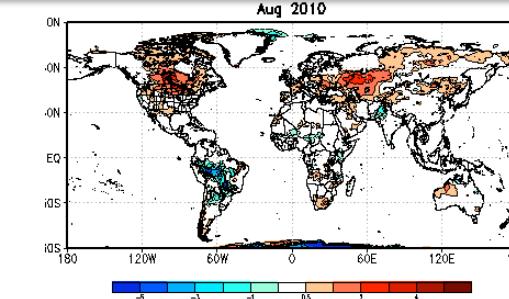
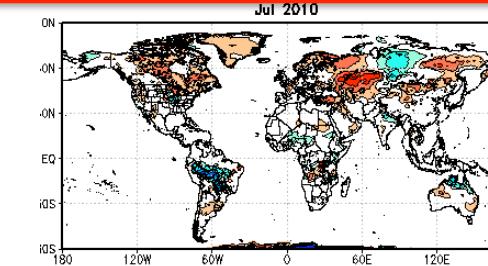
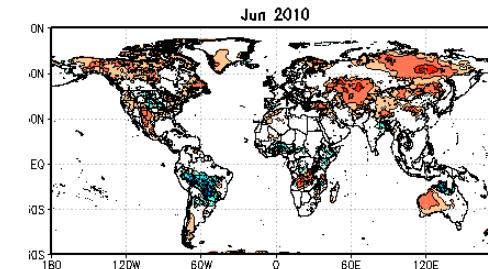
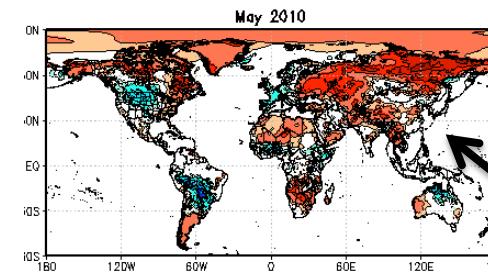
July 2010



August 2010



AGCM Climate SST
(IC May 1)

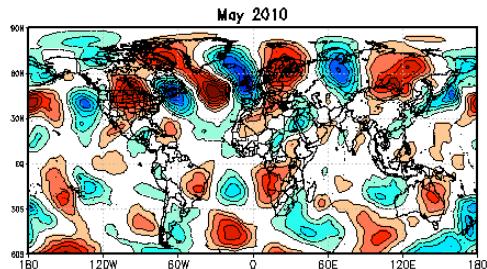


Impact of Land
and Atmospheric
Initial conditions
and land
feedbacks

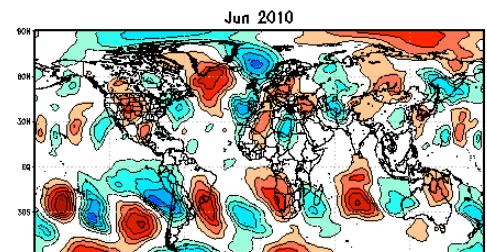
v250mb m/s

MERRA

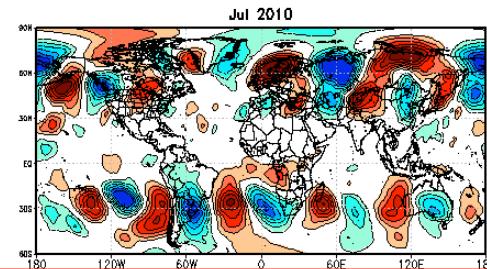
May 2010



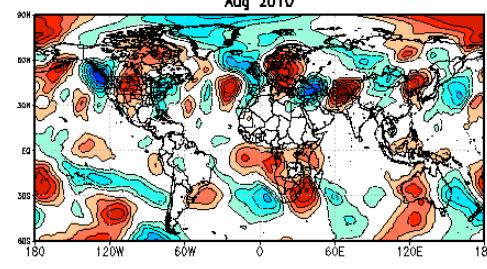
June 2010



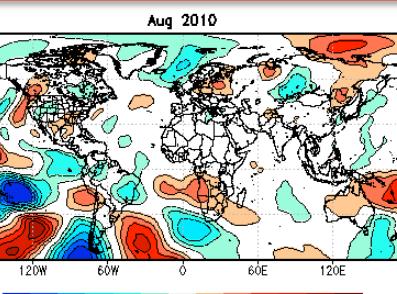
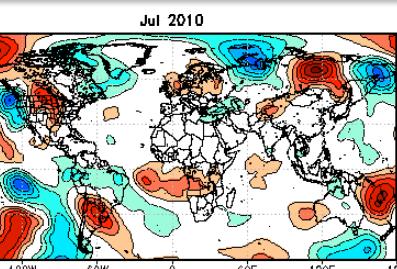
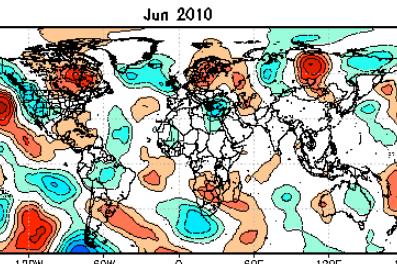
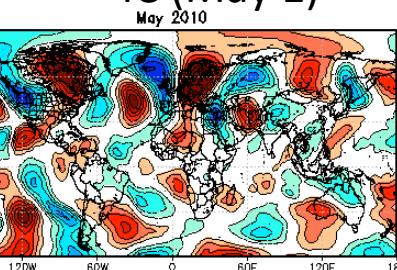
July 2010



August 2010



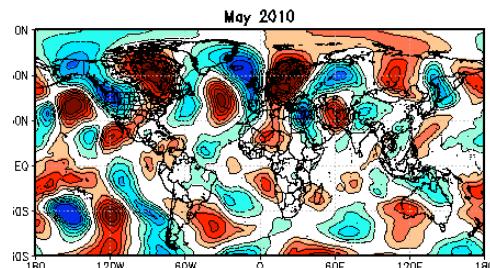
AGCM Observed SST
IC (May 1)



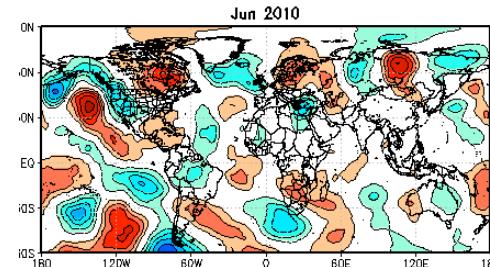
V250mb m/s

AGCM Observed SST
(IC May 1)

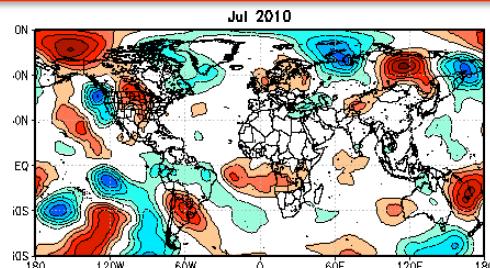
May 2010



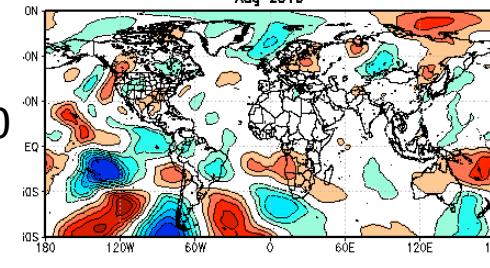
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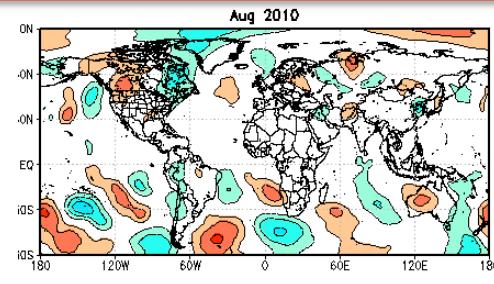
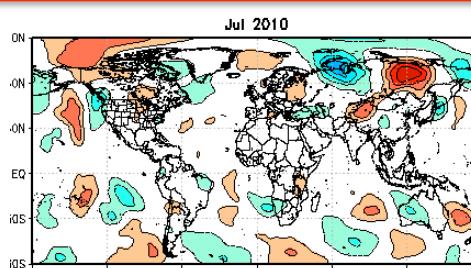
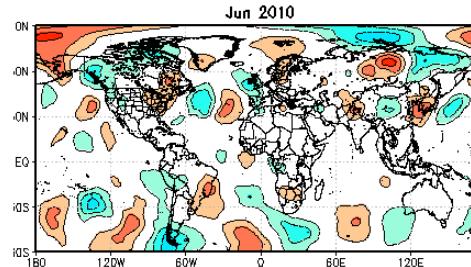
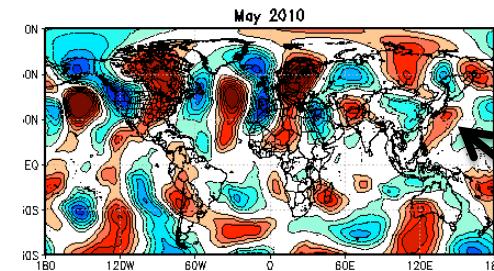
July 2010



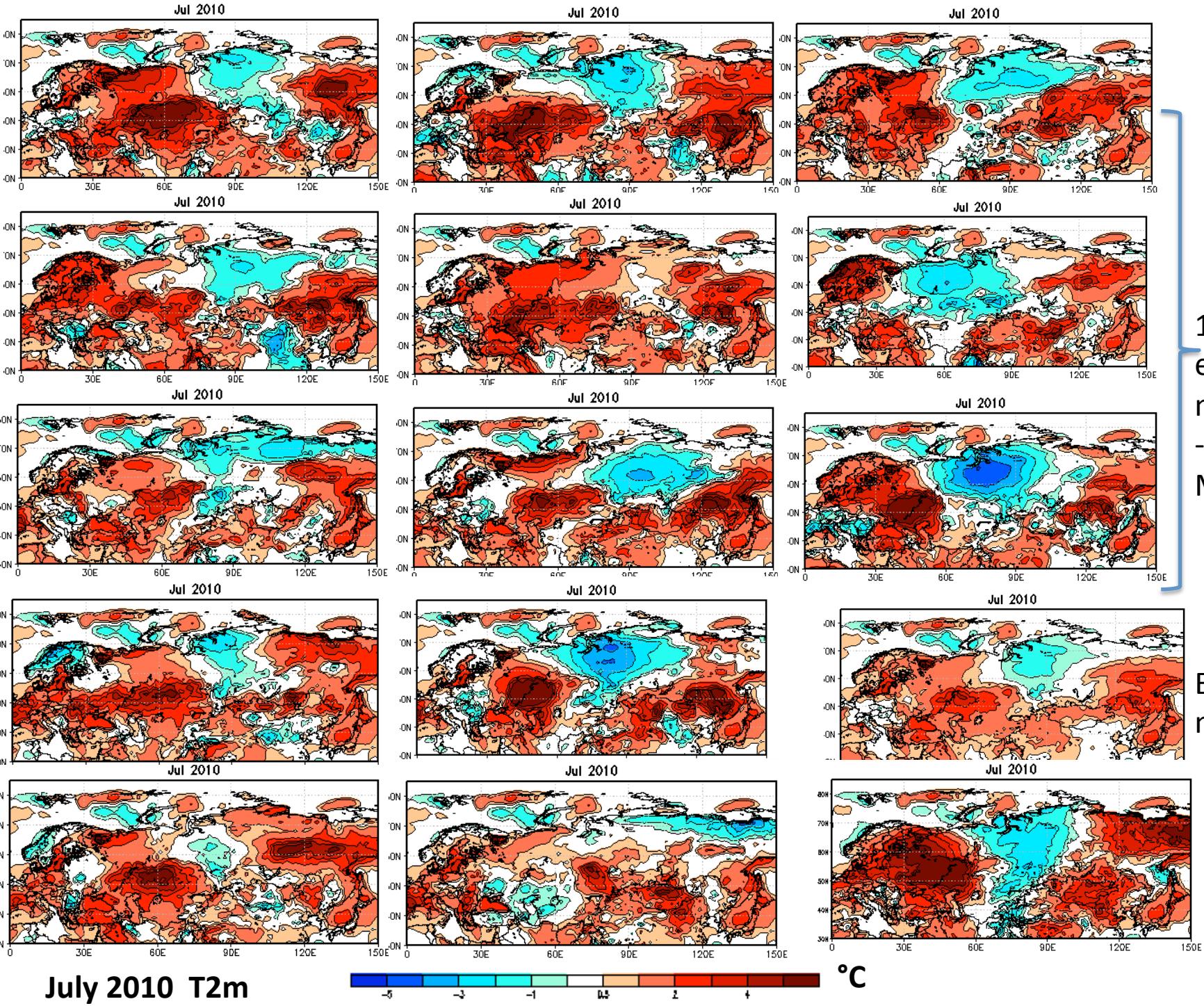
August 2010



AGCM Climate SST
(IC May 1)



Impact of Land
and Atmospheric
Initial conditions
and land
feedbacks



13 of 20
ensemble
members
-initialized
May 1

Ensemble
mean

MERRA

Conclusions: 2010 Russian Heat Wave

- The land appears to be important both in terms of memory of the ICs and feedback (apparently reinvigorating REOF 1 during July)
- Impact of SST is also important for anchoring the key warming areas over southwestern and northeastern Russia
- The extreme heat appears also to have a stochastic element (some ensemble members approach the observed July extremes)

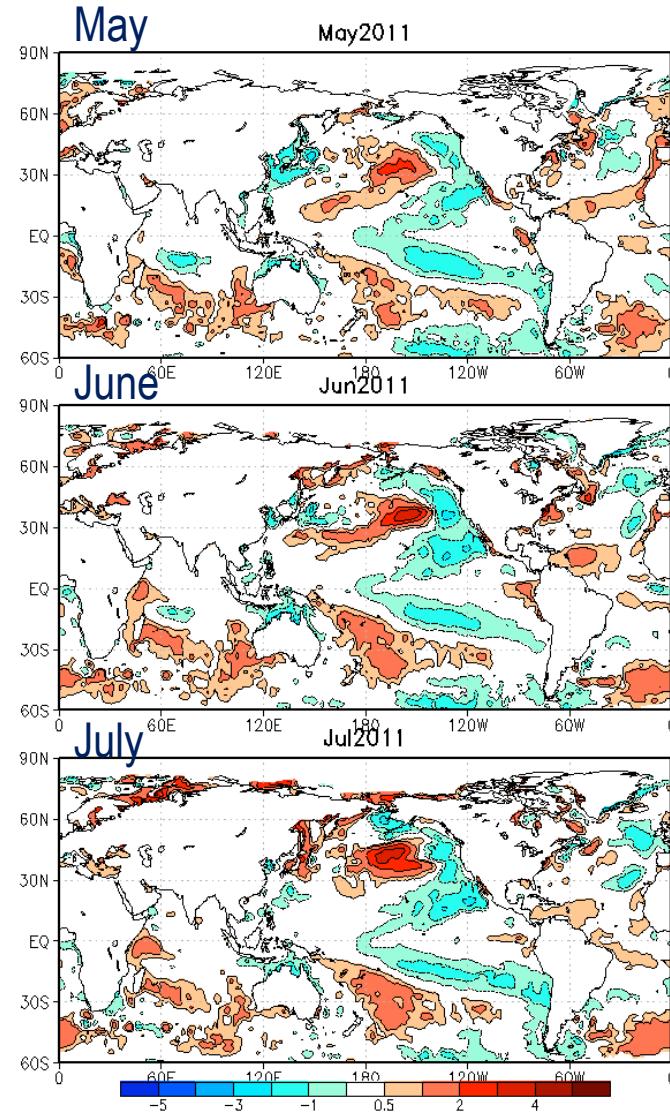
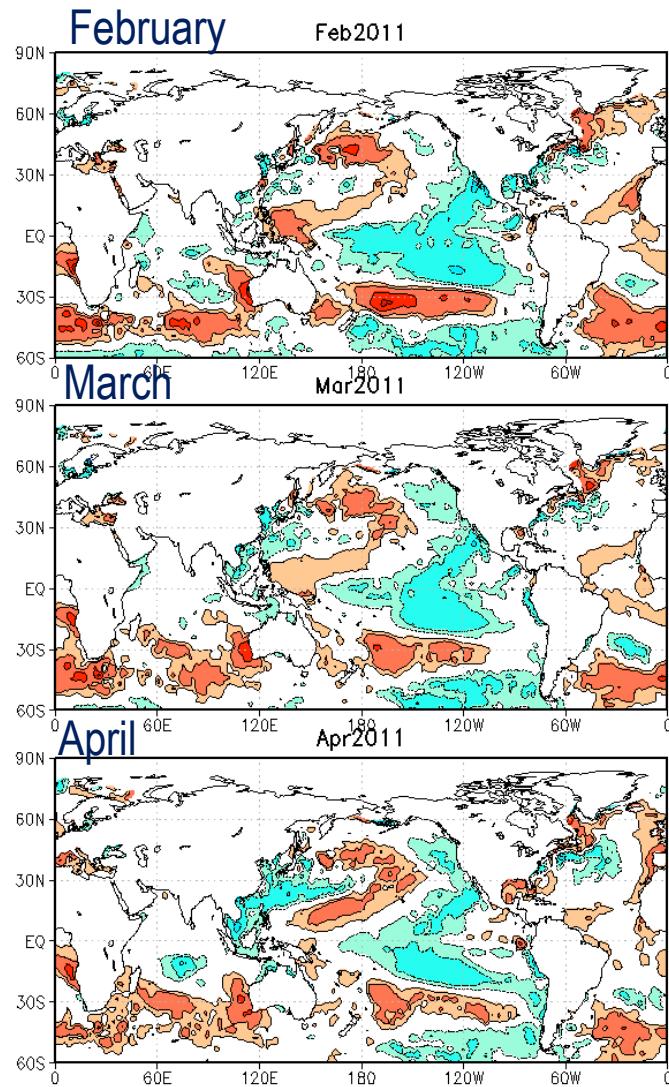
2011

Experiments

- Two sets of 20 ensemble members initialized 1 January and May 1, 2011
- Assess separate impacts of TPac, NPac, TAtl, Natl SST (20 ensemble members each)

Decaying La Niña (2011)

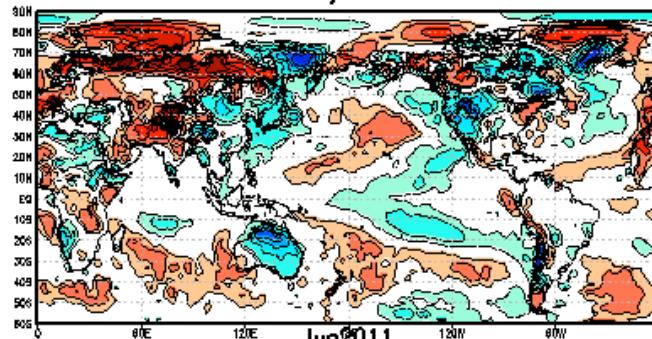
MERRA SfcTemp Anom over ocean



2011 T2m (°C)

NCEP/NCAR

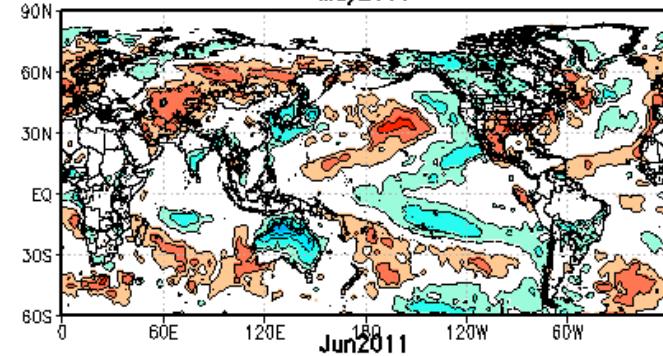
May 2011



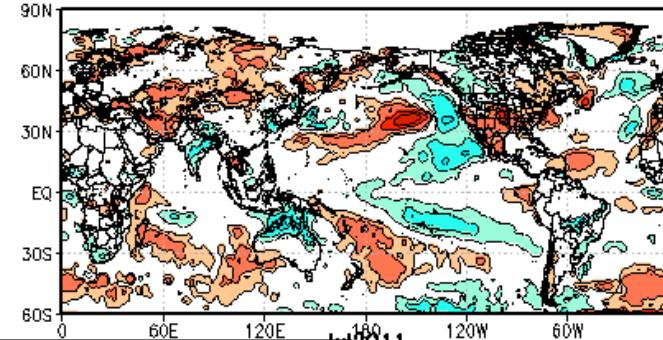
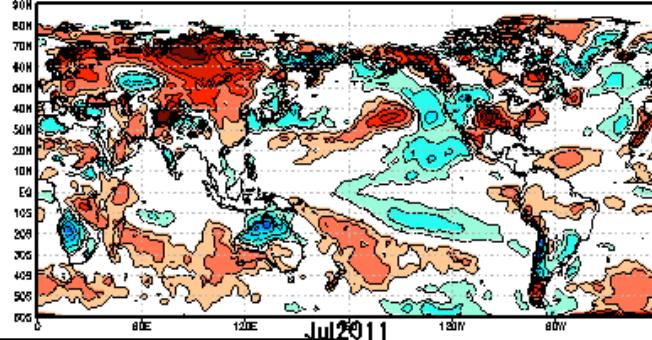
May

AGCM-Initialized
January 1

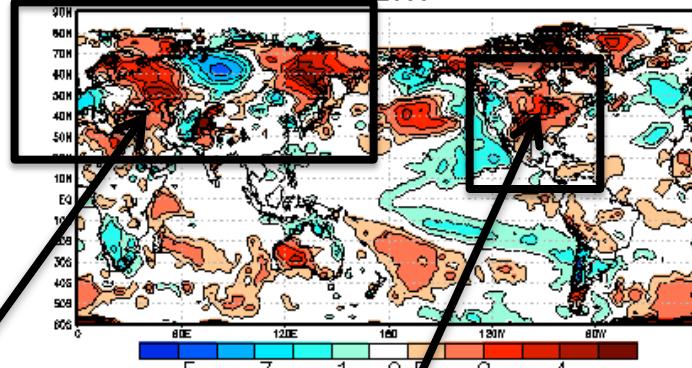
January 1
May 2011



June

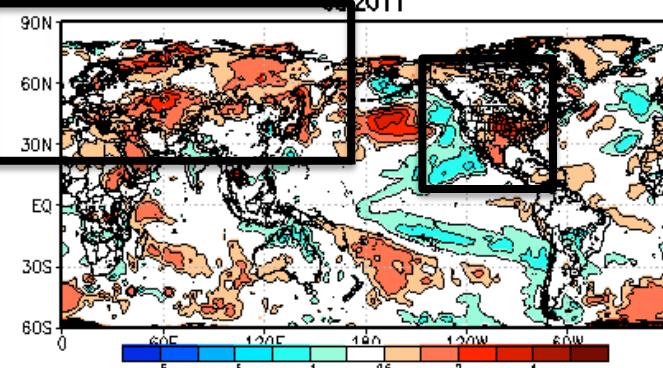


July



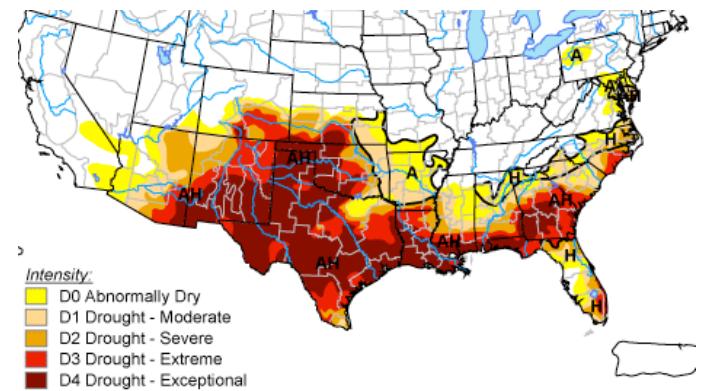
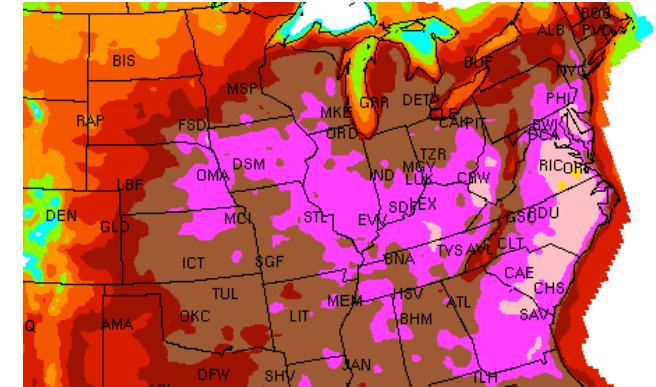
Russian Heat Wave

US Heat Wave and Texas drought

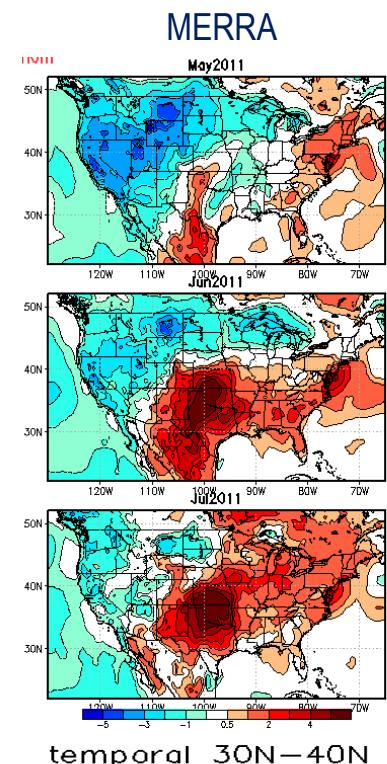


Focus on U.S. Summer Heat Wave

- Central/eastern US record heat wave with continued drought over southern Great Plains (especially Texas) and southeast
- Impact of La Nina, Atlantic SST, soil moisture ?

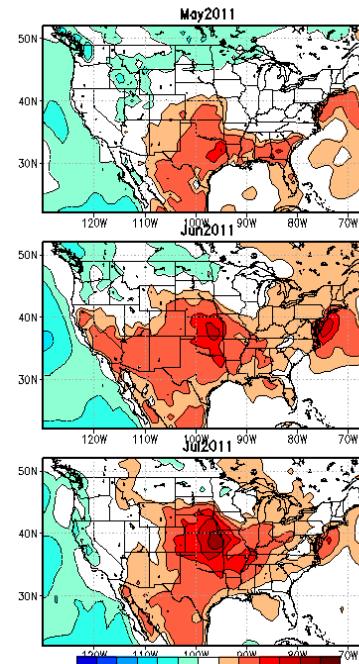


T2m anomalies

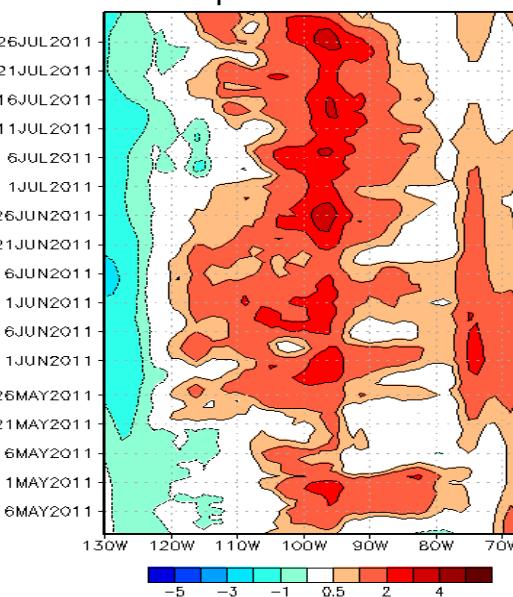


T2m (30N-40N)
spanning 130W to 65W

AGCM EnsMean
(initialized Jan 1)

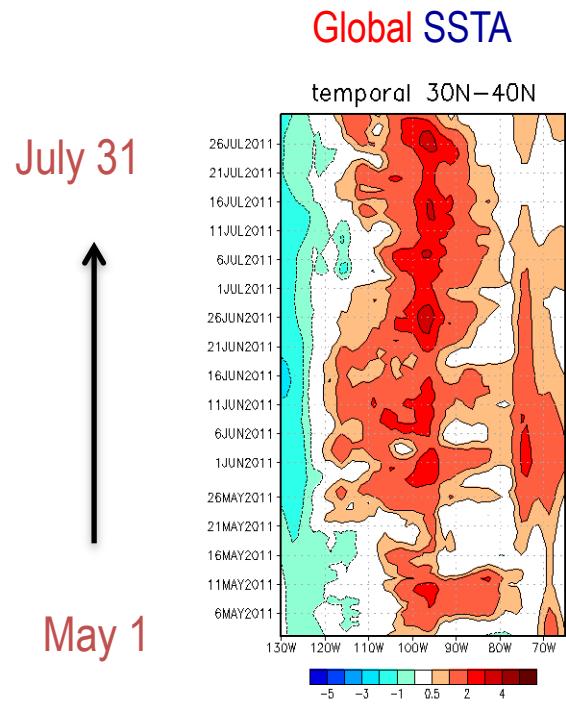


July 31

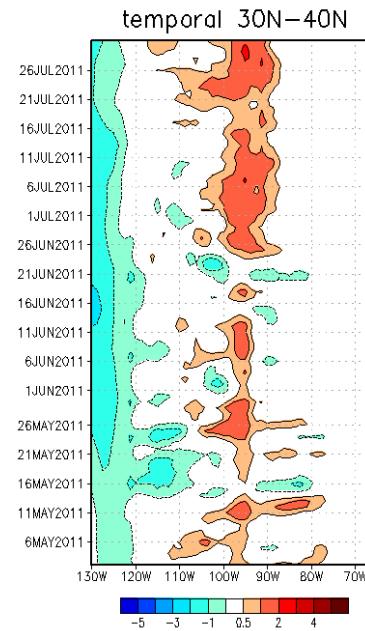


May 1

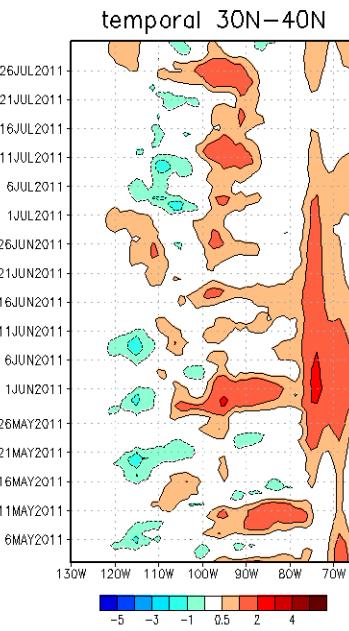




NPac SSTA



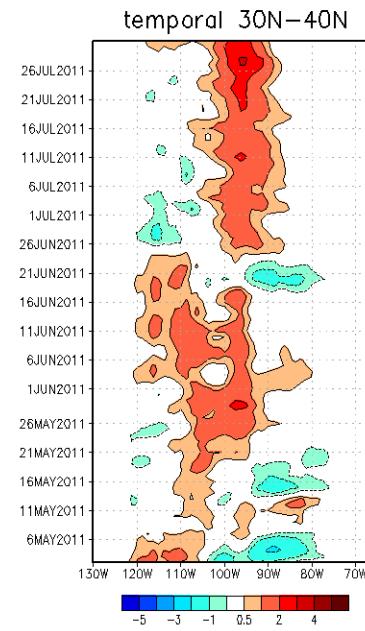
NAtl SSTA



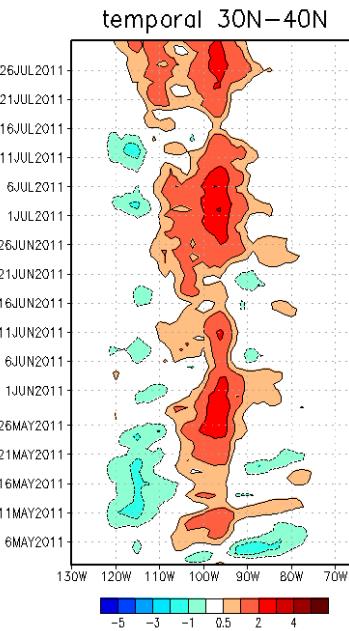
July 31

May 1

TPac SSTA

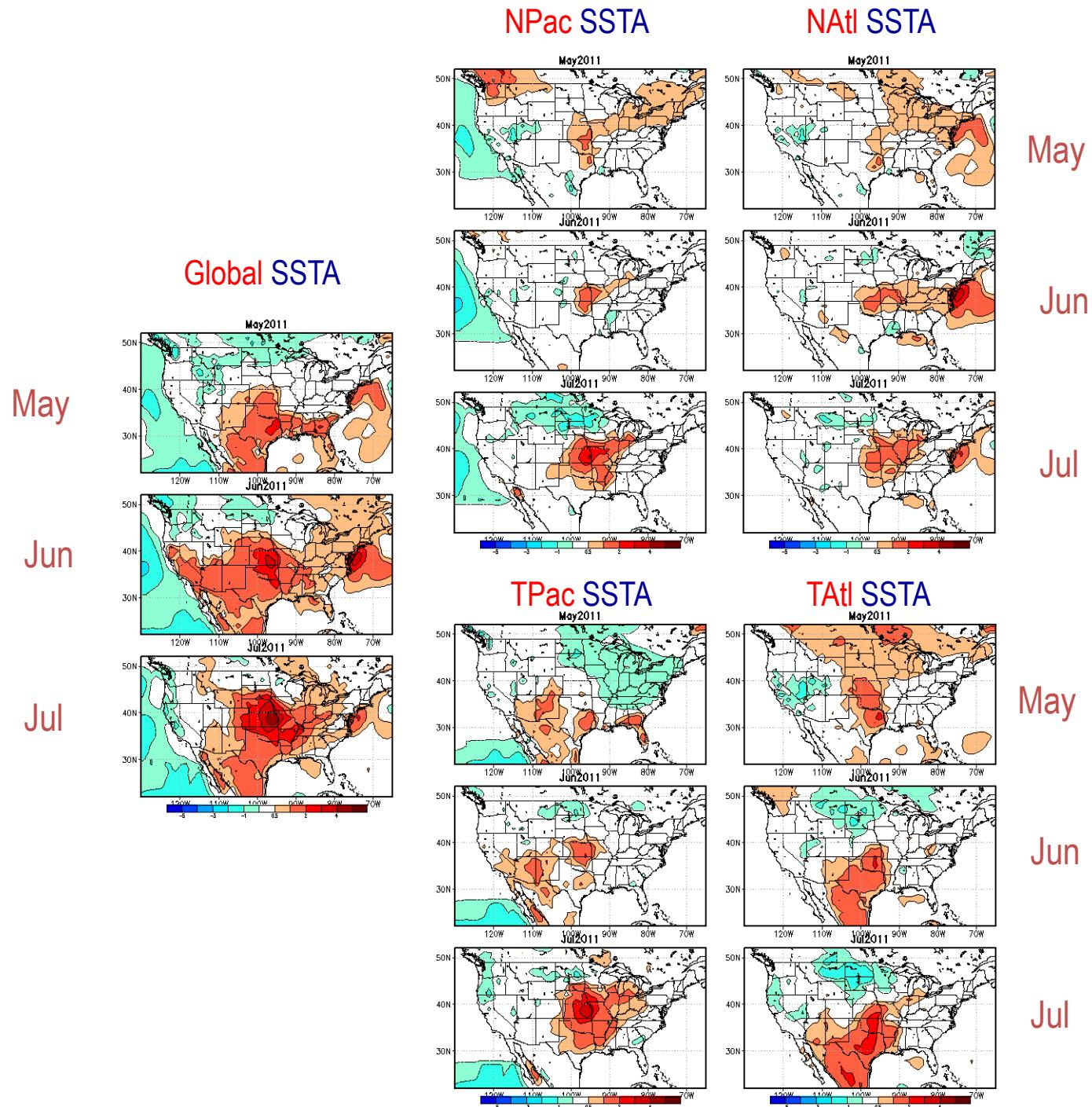


TAtl SSTA



July 31

May 1



Conclusions (2011)

- Central and Eastern US heat wave
 - Tropical and North Pacific SST contribute to the heating in the central Great Plains,
 - the North Atlantic (likely the local off-shore SST) contributed to the east coast heat
- The Texas drought
 - the drought in Texas appears to have developed as a result of La Nina (contrast with summer of 2010 – no Texas drought – still in early stages of La Nina)
 - the warming in the tropical Atlantic appears to be key to the prolonging of the Texas drought (as the La Nina ends)
- The Russian Heat Wave
 - REOF 1 is again playing a key role
 - Surface warming is in part forced by SST

Conclusions (Overall)

- Summer variability occurs largely at monthly and sub-monthly time scales
 - Rossby waves forced by submonthly transients play a key role
 - Basic structure of variability is defined by atmospheric wave properties
 - Limited predictability (order few weeks)
- At times that variability achieves extreme amplitudes and/or extends to longer (seasonal) time scales
 - At times this may simply be stochastic (a reflection of internal variability)
 - At other times both SST and land processes appear to play important roles
 - Linked to regional climate extremes